SEISMIC HAZARD ZONE REPORT 003

SEISMIC HAZARD ZONE REPORT FOR THE ANAHEIM AND NEWPORT BEACH 7.5-MINUTE QUADRANGLES, ORANGE COUNTY, CALIFORNIA

1997 (Revised 2001)

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

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EXECUTIVE SUMMARY

This report summarizes the methods and sources of information used to prepare the Seismic Hazard Zone Maps for the Anaheim and Newport Beach 7.5-minute quadrangles, Orange County, California. The maps display the boundaries of Zones of Required Investigation for liquefaction and earthquake-induced landslides over an area of approximately 120 square miles at a scale of 1 inch = 2,000 feet.

The project area encompasses a portion of the Orange County coastal plain, Newport Mesa, part of Huntington Beach Mesa, a 13-mile stretch of the Santa Ana River, Newport Bay and 8 miles of beaches. The region includes all or parts of Anaheim, Buena Park, Corona Del Mar, Costa Mesa, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Newport Beach, Orange, Placentia, Santa Ana, Stanton, and Westminster. Elevations range from sea level to about 200 feet in the San Joaquin Hills, above Corona Del Mar. The entire area is intensively urbanized.

The maps are prepared by employing geographic information system (GIS) technology, which allows the manipulation of three-dimensional data. Information considered includes topography, surface and subsurface geology, borehole data, historical ground-water levels, existing landslide features, slope gradient, rock-strength measurements, geologic structure, and probabilistic earthquake shaking estimates. The shaking inputs are based upon probabilistic seismic hazard maps that depict peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years.

The liquefaction zone in the Anaheim and Newport Beach quadrangles covers more than 50% of the land area. It is extensive because of the shallow ground-water table and material properties of deposits within the Santa Ana River floodplain. Tertiary marine sedimentary rocks are exposed at the edges of Newport Mesa and the eastern margin of Newport Bay. The steep cliffs in these rocks in the Newport Beach Quadrangle are located within an earthquake-induced landslide zone, which covers less than 2% of the quadrangle. There is no landslide zone in the Anaheim Quadrangle.

How to view or obtain the map

Seismic Hazard Zone Maps, Seismic Hazard Zone Reports and additional information on seismic hazard zone mapping in California are available on the Division of Mines and Geology's Internet page: http://www.consrv.ca.gov/dmg/shezp/

Paper copies of Official Seismic Hazard Zone Maps, released by DMG, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available for purchase from:

BPS Reprographic Services
149 Second Street
San Francisco, California 94105
(415) 512-6550

Seismic Hazard Zone Reports (SHZR) summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These reports are available for reference at DMG offices in Sacramento, San Francisco, and Los Angeles. **NOTE: The reports are not available through BPS Reprographic Services.**

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. They must withhold development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans. The Act also requires sellers (and their agents) of real property within a mapped hazard zone to disclose at the time of sale that the property lies within such a zone. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed DMG to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that 1) the process for zoning liquefaction hazards remain unchanged and 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Zone Report summarizes the development of the hazard zone map. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historical ground-water information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Anaheim and Newport Beach 7.5-minute quadrangles.

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Anaheim and Newport Beach 7.5-Minute Quadrangles, Orange County, California

By
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California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps developed by DMG in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within seismic hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (DOC, 1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This section of the evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Anaheim and Newport Beach 7.5-minute quadrangles. This section, along with Section 2 (addressing earthquake-induced landslides), and Section 3 (addressing potential ground shaking), form a report that is one of a series that summarizes production of similar seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazards zone mapping in California is on DMG's Internet web page: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Liquefaction-induced ground failure has historically been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated, granular sediment within 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern California, most notably in some densely populated valley regions and alluviated floodplains. In addition, the potential for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region in general, including areas in the Anaheim and Newport Beach quadrangles.

METHODS SUMMARY

Characterization of liquefaction hazard presented in this report requires preparation of maps that delineate areas underlain by potentially liquefiable sediment. The following were collected or generated for this evaluation:

- Existing geologic maps were used to provide an accurate representation of the spatial distribution of Quaternary deposits in the study area. Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill

- Construction of shallow ground-water maps showing the historically highest known ground-water levels

- Quantitative analysis of geotechnical data to evaluate liquefaction potential of deposits

- Information on potential ground shaking intensity based on DMG probabilistic shaking maps

The data collected for this evaluation were processed into a series of geographic information system (GIS) layers using commercially available software. The liquefaction zone map was derived from a synthesis of these data and according to criteria adopted by the State Mining and Geology Board (DOC, 2000).

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils generally is confined to areas covered by Quaternary (less than about 1.6 million years) sedimentary deposits. Such areas within the Anaheim and newport beach quadrangles Quadrangle consist mainly of low-lying shoreline regions, alluviated valleys, and floodplains. DMG's liquefaction hazard evaluations are based on information on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth, which is gathered from various sources. Although selection of data used in this evaluation was rigorous, the quality of the data used varies. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations, as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth, density, and thickness of liquefiable materials, depth to ground water, rate of drainage, slope gradient, proximity to free faces, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to assess the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction and zoning evaluations in PART II.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Anaheim and Newport Beach quadrangles cover about 120 square miles in Orange County. The project area encompasses a portion of the Orange County coastal plain, including Newport Mesa and part of Huntington Beach Mesa. The region includes all or parts of Anaheim, Buena Park, Corona Del Mar, Costa Mesa, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Newport Beach, Orange, Placentia, Santa Ana, Stanton, and Westminster. Elevations range from sea level to about 200 feet in the San Joaquin Hills, above Corona Del Mar.

GEOLOGY

Surficial Geology

Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. Geologic mapping of late Quaternary alluvial deposits, digitally compiled by the Southern California Areal Mapping Project (1995), was used to evaluate the areal distribution and character of young, unconsolidated sediments exposed in the Anaheim and Newport Beach quadrangles. These geologic maps relied extensively on early surficial soil surveys (Echmann and others, 1916), to which geologic nomenclature was applied.

The mapped units fall into four basic age groups: (1) late Pleistocene (?) alluvium associated with the Coyote Hills, (2) late Pleistocene (?) marine terrace deposits, which cover the Huntington Beach and Newport mesas, and part of the San Joaquin Hills, (3) Holocene alluvial fan deposits associated with the active Coyote Creek, Santa Ana River, and Santiago Creek alluvial systems, (4) modern beach sands and extensive lagoonal deposits. In addition, numerous areas are covered by artificial fill.

Structural Geology

The Anaheim 7.5-minute Quadrangle portion of the Orange County coastal plain is bound on the north by the inferred trace of the Norwalk Fault Zone and the late Pleistocene fan deposits associated with the adjacent anticlinal hills of the Coyote Hills Uplift (Greenwood and Morton, 1990). The main body of this quadrangle is underlain by the broad, northwest-plunging synclinal Los Angeles Basin, which includes up to 4200 feet of relatively unconsolidated Pleistocene marine and non-marine sediments (Greenwood, 1980b) and up to 170 feet of unconsolidated non-marine sediments (Fuller, 1980a).

The Newport Beach 7.5-minute Quadrangle part of the study area includes the broad southern margin of the Los Angeles Basin, which culminates abruptly with the Newport-Inglewood Uplift. This uplift is characterized by broadly warped coastal mesas of late Miocene to early Pleistocene marine sediments and late Pleistocene marine terrace deposits, which are deeply incised by the antecedent ancestral Santa Ana River system of latest Pleistocene to earliest Holocene.

ENGINEERING GEOLOGY

Lithologic descriptions and soil-test results included in boreholes were analyzed to determine the geotechnical properties of various Quaternary stratigraphic units. Geotechnical data within the project area were collected for more than 500 project sites where one or more test holes were drilled (Plates 1.1 and 1.2). Borehole logs were collected from the files of the City of Anaheim Public Utilities Department, the City of Santa Ana Public Works Department, Environmental Health Division of the Orange County Public Health Department, Municipal Water District of Orange County, Construction and Design Divisions of the Orange County Environmental Management Agency, California Department of Water Resources, California Department of Transportation (Caltrans), and private consultants.

An analysis of the local subsurface geology reveals a dynamic interaction between three lithologically distinct primary fan systems: the Santa Ana River Fan, the Coyote Creek Fan, and the Santiago Creek Fan. The temporal depositional reference frame is controlled by the last low stand of sea level -- approximately 20,000 years ago (McNeilan and others, 1996). During this time, local drainages became incised because of lower base levels.

Standard Penetration Test (SPT) data provide a standardized measure of the penetration resistance of a geologic deposit and commonly are used as an index of density. Many geotechnical investigations record SPT data, including the number of blows by a 140-pound drop weight required to drive a sampler of specific dimensions one foot into the soil. Recorded blow counts for non-SPT geotechnical sampling, where the sampler diameter, hammer weight or drop distance differ from those specified for an SPT (ASTM D1586), were converted to SPT-equivalent blow count values and entered into the DMG GIS. The actual and converted SPT blow counts were normalized to a common reference effective overburden pressure of 1 atmosphere (approximately 1 ton per square foot) and a hammer efficiency of 60% using a method described by Seed and Idriss (1982) and Seed and others (1985). This normalized blow count is referred to as $(N_1)_{60}$.

Stratigraphic units were first identified via correlations of lithology and standard penetration tests (SPT) of deep geotechnical boreholes (generally 60 to 80 feet) along U.S. Interstate 5 (I-5). These detailed geotechnical borehole logs were placed in cross sections having a horizontal scale of 1"=1000', with a vertical scale of 1"=10'. Similar-scale cross sections were then prepared along U.S. highways I-91, I-22, I-405, and I-55, within the Anaheim and the Newport Beach quadrangles.

The stratigraphic model was then regionally extrapolated with a series of north-south and east-west trending cross sections prepared from environmental geotechnical boreholes (primarily leaking underground storage tank studies), and anchored either by other deep hospital-site boreholes or by detailed water-well logs.

Lower Holocene aquifers

The stratigraphic base of the Holocene is related to the late Pleistocene rise in sea level, which raised stream-base levels, that led to the deposition of fan sediments. This fluvial backfilling of incised drainages controlled the initial distribution of coarse-grained sediments, locally named the Bolsa and Talbert aquifers (Mendenhall, 1905). This depositional process has been well documented in Poland, Piper, and others (1956) and Poland (1959). The depth to base, thickness, and lateral distribution of these Holocene aquifers was mapped by Fuller (1980b), who showed the top of these aquifers to be generally greater than 70 feet deep. The immediate scope of the present study focuses on geologic conditions within 50 feet of the ground surface, however, an appreciation of these underlying aquifers aids in establishing a stratgraphic framework for determining the nature and distribution of overlying, potentially liquefiable sediments.

Mid-Holocene to modern sediments

The surface distribution of Holocene sediments, as recorded in early editions of regional soil survey maps (Eckmann and others, 1919), suggests that the Santa Ana River has recently wandered back and forth across the Orange County coastal plain from Alamitos Bay to Newport Bay. Historical accounts and documents further support the process of widespread sheet flooding being the dominant depositional process associated with the Santa Ana River, prior to the construction of Prado Dam in 1941 (California Department of Water Resources, 1959).

Constructing regional cross sections using Caltrans and underground tank borehole data, allowed the definition of at least six repetitive, upward-fining sequences of fluvial sediments, with recognizable lateral continuity. The cross-sectional models became better defined as local cases of cross-cutting relationships and longitudinal facies changes also became apparent.

The cross sections demonstrated that some younger sand and silt deposits may be as extensive and continuous, from the coastal plain through the Santa Ana gap, as are the underlying Bolsa and Talbert aquifers. The cross sections also show stratigraphically complex interfluvial sediments as demonstrated by local and regional occurrences of peat deposits.

The north-south trending cross sections reveal the subsurface character of the northern margin of Newport Mesa. On the north, the mesa locally lacks the steep surface and subsurface topographic expression that is more typically associated with the west and east flanks of the mesa. Topography and subsurface interpretations suggest the occurrence of a west-northwest-trending, very recent stream channel, which is filled with poorly to well-sorted sand. This channel is apparently incised in the gently north-dipping margin of Newport Mesa, and appears to be up to 1.25 miles wide, 10 to 15 feet deep, and likely extends as much as 2.5 miles easterly from the present Santa Ana River.

GROUND-WATER CONDITIONS

Liquefaction hazard may exist in areas where depth to ground water is 40 feet or less. DMG uses the highest known ground-water levels because water levels during an earthquake cannot be anticipated because of the unpredictable fluctuations caused by natural processes and human activities. A historical-high ground-water map differs from most ground-water maps, which show the actual water table at a particular time. Plate 1.2 depicts a hypothetical ground-water table within alluviated areas.

Ground-water conditions were investigated in the Anaheim and Newport Beach quadrangles to evaluate the depth to saturated materials. Saturated conditions reduce the effective normal stress, thereby increasing the likelihood of earthquake-induced liquefaction (Youd, 1973). Ground-water depth data were obtained from compiled geotechnical boreholes, water-well logs, and environmental monitoring wells. The depths to first-encountered water, free of piezometric influences, were plotted onto maps of the project area showing depths to historically shallowest ground water (Plates 1.1 and 1.2). These maps were developed using results of ground-water hydrologic modeling performed during this study and earlier studies conducted by Greenwood (1980a) and then digitized and used for the liquefaction analysis.

PART II

LIQUEFACTION POTENTIAL

Liquefaction may occur in water-saturated sediment during moderate to great earthquakes. Liquefied sediment loses strength and may fail, causing damage to buildings, bridges, and other structures. Many methods for mapping liquefaction hazard have been proposed. Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of liquefaction susceptibility and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce a liquefaction potential map. Liquefaction susceptibility is a function of the capacity of sediment to resist liquefaction. Liquefaction opportunity is a function of the potential seismic ground shaking intensity.

The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985). Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for their mapping of liquefaction hazards in the Los Angeles region. This method combines geotechnical analyses, geologic and hydrologic mapping, and probabilistic earthquake shaking estimates, but follows criteria adopted by the State Mining and Geology Board (DOC, 2000).

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of a soil to loss of strength when subjected to ground shaking. Physical properties of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance to liquefaction. Some of these properties can be correlated to a sediment's geologic age and environment of deposition. With increasing age, relative density may increase through cementation of the particles or compaction caused by the weight of the overlying sediment. Grain-size characteristics of a soil also influence susceptibility to liquefaction. Sand is more susceptible than silt or gravel, although silt of low plasticity is treated as liquefiable in this investigation. Cohesive soils generally are not considered susceptible to liquefaction. Such soils may be vulnerable to strength loss with remolding and represent a hazard that is not addressed in this investigation. Soil characteristics and processes that result in higher measured penetration resistances generally indicate lower liquefaction susceptibility. Thus, blow count and cone penetrometer values are useful indicators of liquefaction susceptibility.

Saturation is required for liquefaction, and the liquefaction susceptibility of a soil varies with the depth to ground water. Very shallow ground water increases the susceptibility to liquefaction (soil is more likely to liquefy). Soils that lack resistance (susceptible soils) typically are saturated, loose and sandy. Soils resistant to liquefaction include all soil types that are dry, cohesive, or sufficiently dense.

DMG's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps and historical occurrences, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil properties and soil conditions such as type, age, texture, color, and consistency, along with historical depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, liquefaction susceptibility maps typically are similar to Quaternary geologic maps. DMG's qualitative susceptible soil inventory is summarized below.

Holocene deposits

The majority of the boreholes drilled in areas underlain by Holocene sediments and marked by historic shallow ground-water depth (less than 40 feet) penetrated layers where the factor of safety against liquefaction is less than 1. This reflects the widespread distribution of loose sandy material in the subsurface Quaternary deposits and the anticipated high peak horizontal ground acceleration. The map characterizes the liquefaction susceptibility of all such soils as high.

Pleistocene deposits

Liquefaction analyses of Pleistocene sedimentary layers, with few exceptions, resulted in factors of safety greater than 1.0. One area, on the northern flank of Costa Mesa, has inferred Pleistocene San Pedro Formation sediments that produced factors of safety less than 1.0. Further evaluation of these deposits in the immediate area revealed that the lateral extent of the liquefiable materials was very limited and generally at depths greater than 35 feet. Further, it was found that there are no known free-face conditions that would contribute to lateral spreading in this area. Therefore, all Pleistocene deposits have been mapped as having low susceptibility to liquefaction.

LIQUEFACTION OPPORTUNITY

Liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for strong ground shaking. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10% probability of exceedance over a 50-year period (DOC, 2000). The earthquake magnitude used in DMG's analysis is the magnitude that contributes most to the calculated PGA for an area.

For the Anaheim and Newport Beach quadrangles, a peak acceleration of 0.4g resulting from an earthquake of magnitude 6.8 was used for liquefaction analyses. The PGA and magnitude values were based on de-aggregation of the probabilistic hazard at the 10% in 50-year hazard level (Petersen and others, 1996; Cramer and Petersen, 1996). See the ground motion section (3) of this report for further details.

Quantitative Liquefaction Analysis

DMG performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; Seed and others, 1985; National Research Council, 1985; Seed and Harder, 1990; Youd and Idriss, 1997). This procedure calculates soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR) based on standard penetration test (SPT) results, ground water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The factor of safety (FS) relative to liquefaction is: FS=CRR/CSR. FS, therefore, is a quantitative measure of liquefaction potential. DMG uses a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, to indicate the presence of potentially liquefiable soil. While an FS of 1.0 is considered the “trigger” for liquefaction, for a site specific analysis an FS of as much as 1.5 may be appropriate depending on the vulnerability of the site related structures. For a regional assessment DMG normally has a range of FS that results from the liquefaction analyses. The DMG liquefaction analysis program calculates an FS at each sample that has blow counts. The lowest FS in each borehole is used for that location. These FS vary in reliability according to the quality of the geotechnical data. These FS as well as other considerations such as slope, free face conditions, and thickness and depth of potentially liquefiable soil are evaluated in order to construct liquefaction potential maps, which then directly translate to zones of required investigation**.**

More than 300 geotechnical borehole logs were reviewed in this study (Plates 1.1 and 1.2). Most include blow-count data from SPT’s or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2 1/2-inch inside diameter ring samplers, were translated to SPT-equivalent values if reasonable factors could be used in conversion calculations. The reliability of the SPT-equivalent values varies. Therefore, they are weighted and used in a more qualitative manner. Few borehole logs, however, include all of the information (soil density, moisture content, sieve analysis, etc) required for an ideal Seed Simplified Analysis. For boreholes having acceptable penetration tests, liquefaction analysis is performed using logged density, moisture, and sieve test values or using average test values of similar materials.

LIQUEFACTION ZONES

Criteria for Zoning

Areas underlain by materials susceptible to liquefaction during an earthquake were included in liquefaction zones using criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the California State Mining and Geology Board (DOC, 2000). Under those guideline criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historical earthquakes

2. All areas of uncompacted artificial fill containing liquefaction-susceptible material that are saturated, nearly saturated, or may be expected to become saturated

3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable

4. Areas where existing geotechnical data are insufficient

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historical high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (11,000 to 15,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historical high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria to liquefaction zoning in the Anaheim and Newport Beach quadrangles is summarized below.

Liquefaction-related ground settlement and displacement associated with the Long Beach earthquake of March 10, 1933 caused significant effects in the so-called Santa Ana Gap area, between Huntington Beach and Newport mesas, and along the coastal regions as summarized in Cole (1981). All such localities are included within liquefaction zones.

Artificial Fills

Non-engineered artificial fill typically consists of loose sandy soils whose liquefaction susceptibility is high. Extensive areas of lagoonal fills were recognized by regional soil surveys in the coastal Santa Ana Gap and Newport Bay areas, and are included in the category of artificial fill. These areas are included within liquefaction zones.

Areas with Sufficient Existing Geotechnical Data

Sufficient geotechnical data exist for most of the regions because most urban development in the study area has occurred over the last 5 decades. During this time, local agencies have required geotechnical site investigations for construction, environmental-cleanup projects, and flood-control projects. Data from these site investigations were used to develop a liquefaction susceptibility map discussed in the Liquefaction Susceptibility section of this report. Areas characterized by soils having high liquefaction susceptibility were placed in liquefaction zones. These areas contain loose sandy soils of Holocene age where historic shallowest water depth is less than 40 feet. Areas covered by Pleistocene sediments were excluded from liquefaction zones because liquefaction susceptibility of these sediments is generally low.

Areas with Insufficient Existing Geotechnical Data

Negligible areas in the extensively urbanized regions lacked geotechnical borehole log data.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Anaheim and Newport Beach 7.5-Minute Quadrangles, Orange County, California

By
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Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps prepared by DMG in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997; also available on the Internet at http://www.consrv.ca.gov/pubs/sp/117/).

This section of the evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Anaheim and Newport Beach 7.5-minute quadrangles. This section, along with Section 1 (addressing liquefaction), and Section 3 (addressing earthquake shaking), form a report that is one of a series that summarizes the preparation of seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet web page: http://www.consrv.ca.gov/dmg/shezp/.

BACKGROUND

Landslides triggered by earthquakes historically have been a significant cause of earthquake damage. In California, large earthquakes such as the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes triggered landslides that were responsible for destroying or damaging numerous structures, blocking major transportation corridors, and damaging life-line infrastructure. Areas that are most susceptible to earthquake-induced landslides are steep slopes in poorly cemented or highly fractured rocks, areas underlain by loose, weak soils, and areas on or adjacent to existing landslide deposits. These geologic and terrain conditions exist in many parts of California, including numerous hillside areas that have already been developed or are likely to be developed in the future. The opportunity for strong earthquake ground shaking is high in many parts of California because of the presence of numerous active faults. The combination of these factors constitutes a significant seismic hazard throughout much of California, including the hillside areas of the Anaheim and Newport Beach quadrangles.

METHODS SUMMARY

The mapping of earthquake-induced landslide hazard zones presented in this report is based on the best available terrain, geologic, geotechnical, and seismological data. If unavailable or significantly outdated, new forms of these data were compiled or generated specifically for this project. The following were collected or generated for this evaluation:

- Digital terrain data were used to provide an up-to-date representation of slope gradient and slope aspect in the study area

- Geologic mapping was used to provide an accurate representation of the spatial distribution of geologic materials in the study area. In addition, a map of existing landslides, whether triggered by earthquakes or not, was prepared

- Geotechnical laboratory test data were collected and statistically analyzed to quantitatively characterize the strength properties and dynamic slope stability of geologic materials in the study area

- Seismological data in the form of DMG probabilistic shaking maps and catalogs of strong-motion records were used to characterize future earthquake shaking within the mapped area

The data collected for this evaluation were processed into a series of GIS layers using commercially available software. A slope stability analysis was performed using the Newmark method of analysis (Newmark, 1965), resulting in a map of landslide hazard potential. The earthquake-induced landslide hazard zone was derived from the landslide hazard potential map according to criteria developed in a DMG pilot study (McCrink and Real, 1996) and adopted by the State Mining and Geology Board (DOC, 2000).

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered from a variety of outside sources. Although the selection of data used in this evaluation was rigorous, the quality of the data is variable. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Due to limitations in methodology, it should be noted that these zone maps do not necessarily capture all potential earthquake-induced landslide hazards. Earthquake-induced ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. It should also be noted that no attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Anaheim and Newport Beach quadrangles, for more information on the delineation of liquefaction zones.

The remainder of this report describes in more detail the mapping data and processes used to prepare the earthquake-induced landslide zone map for the Anaheim and Newport Beach quadrangles. The information is presented in two parts. Part I covers physiographic, geologic and engineering geologic conditions in the study area. Part II covers the preparation of landslide hazard potential and landslide zone maps.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Anaheim and Newport Beach quadrangles cover approximately 120 square miles in Orange County. The project area encompasses a portion of the Orange County coastal plain and the ancestral Santa Ana River flood plain. The region includes all or parts of Anaheim, Buena Park, Corona Del Mar, Costa Mesa, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Newport Beach, Orange, Placentia, Santa Ana, Stanton, and Westminster. The only substantial topographic relief in the area occurs along the bluffs of the Newport mesa and part of the Huntington Beach Mesa. Elevations range from sea level to about 200 feet in the San Joaquin Hills, above Corona Del Mar.

Digital Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. An accurate slope gradient calculation begins with an up-to-date map representation of the earth's surface. Within the Anaheim and Newport Beach quadrangles, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, which was prepared from the 7.5-minute quadrangle topographic contours that are based on 1963 aerial photography, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy.

A slope map was made from the DEM using a third-order, finite difference, center-weighted algorithm (Horn, 1981). The DEM was also used to make a slope aspect map. The manner in which the slope and aspect maps were used to prepare the zone map will be described in subsequent sections of this report.

GEOLOGY

Bedrock and Surficial Geology

The geologic mapping in this area was published in 1981 by DMG (Morton and Miller, 1981) and digitally compiled by the Southern California Areal Mapping Project in 1995. These maps were modified to reflect the most recent mapping in the area. Landslide deposits were deleted from the map so that the distribution of bedrock formations and the landslide inventory would exist on separate layers for the hazard analysis. In the field, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units. In addition, the relation of the various geologic units to development and abundance of slope failures was noted.

The mapped units used in this landslide analysis are from two basic groups: 1) the Tertiary marine sedimentary rock units of the Monterey, Capistrano and Niguel formations, which underlie the bluff areas along mesas; and, 2) the late Pleistocene to Holocene marine terraces deposits, alluvial fans, stream alluvium, modern beach sands and lagoonal deposits that comprise the surficial cover over the flat-lying areas. Much of the area has been developed and is currently covered to varying depths by artificial fill.

Pre-Quaternary deposits: The oldest geologic units mapped in the Anaheim and Newport Beach quadrangles are the Tertiary marine rocks that underlie the bluffs of the Newport Beach Mesa. The Monterey Formation (Middle to upper Miocene) consists of thin-bedded marine siltstone and siliceous shale. The Niguel Formation (Pliocene to Pleistocene) is composed of massive fine-grained sandstone. The Capistrano Formation (Pliocene) consists of the siltstone facies of a highly variable rock unit. One area, on the south bluff of the Huntington Beach mesa, is underlain by Pleistocene San Pedro Formation sediments.

Capping these units are Quaternary to Recent marine terrace deposits, colluvium, and alluvium.

Quaternary deposits: The surface distribution of the Quaternary to Holocene sediments suggests that the Santa Ana River has deposited sediments across the Orange County coastal plain from Alamitos Bay to Newport Bay. Historical accounts and documents further support that widespread sheet flooding was the dominant depositional process associated with the Santa Ana River prior to the construction of Prado Dam in 1941 (California Department of Water Resources, 1959). A more detailed discussion of the Quaternary deposits in the Anaheim area can be found in Section 1.

***Artificial fills*:** Non-engineered artificial fill typically consists of loose sandy soil. Extensive areas of lagoonal fills that were mapped during regional soil surveys in the coastal Santa Ana Gap and Newport Bay areas are included in the category of artificial fill.

Structural Geology

The Anaheim 7.5-minute Quadrangle portion of the Orange County coastal plain is bound on the north by the inferred trace of the Norwalk Fault Zone and the late Pleistocene fan deposits associated with the adjacent anticlinal hills of the Coyote Hills Uplift (Greenwood and Morton, 1990). The main body of this quadrangle is underlain by the broad, northwest-plunging synclinal Los Angeles Basin, which includes up to 4,200 feet of relatively unconsolidated Pleistocene marine and non-marine sediments (Greenwood, 1980b) and up to 170 feet of unconsolidated non-marine sediments (Fuller, 1980a).

The Newport Beach 7.5-minute Quadrangle part of the study area includes the broad southern margin of the Los Angeles Basin, which culminates abruptly with the Newport-Inglewood Uplift. This uplift is characterized by broadly warped coastal mesas of late Miocene to early Pleistocene marine sediments and late Pleistocene marine terrace deposits, which are deeply incised by the antecedent ancestral Santa Ana River system of latest Pleistocene to earliest Holocene age.

Because of the relatively shallow dip of bedding and homogeneous character of the Tertiary rock units, it was determined that the underlying geologic structure does not significantly impact the slope stability of the sedimentary rock units in this area.

Landslide Inventory

The evaluation of earthquake-induced landsliding requires an up-to-date and complete picture of the previous occurrence of landsliding. Previous geologic mapping at the 1:48,000 (Morton and Miller, 1981) and 1:12,000 (Tan and Edgington, 1976) scales indicates that there are no deep-seated landslides associated with either of these quadrangles. The main surficial instability is shallow surface raveling and localized debris flows along the steeper bluff faces and canyons near the edges of mesas. A reconnaissance landslide inventory, based on field observations and analysis of aerial photos (Whittier-Fairchild, 1927; see Air Photos), indicates that no mappable existing landslides are within the Anaheim and Newport Beach quadrangles. Data related to the material strength of existing landslide materials are included in Tables 2.1 and 2.2.

ENGINEERING GEOLOGY

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, the geologic map units described above were ranked and grouped on the basis of their shear strength. Generally, the primary source for rock shear-strength measurements is geotechnical reports prepared by consultants on file with local government permitting departments. Shear strength data for the rock units identified on the geologic map were obtained from the City of Laguna Beach (see Appendix A). Geotechnical and engineering geologic reports contained in Environmental Impact Reports and Hospital Review Project files at DMG are additional sources. Other sources include reports published in professional journals, and summaries of “state of the practice” values for some widespread formations in the region provided by practicing professionals and local government geologists. The locations of rock and soil samples taken from the Newport Beach Quadrangle for shear testing are shown on Plate 2.1.

Shear strength data gathered from the above sources were compiled for each geologic map unit. Geologic units were grouped on the basis of average angle of internal friction (average phi) and lithologic character. Average (mean and median) phi values for each geologic map unit and corresponding strength group are summarized in Table 2.1. For most of the geologic strength groups in the map area, a single shear strength value was assigned and used in our slope stability analysis. A geologic material strength map was made based on the groupings presented in Tables 2.1 and 2.2, and this map provides a spatial representation of material strength for use in the slope stability analysis.

The results of the grouping of geologic materials in the Anaheim and Newport Beach quadrangles are in Tables 2.1 and 2.2.

ANAHEIM AND NEWPORT BEACH QUADRANGLES
SHEAR STRENGTH GROUPINGS

	Formation Name	Number Tests	Mean/Median PHI	Group Mean/Median PHI (deg.)	Group Mean/Median Cohesion (psf)	No Data: Similar Lithology	Phi Values Used in Stability Analyses
GROUP 1	Tm	3	31.3 / 30.2				
	Tcs/Tcs?	2	30.2 / 31	30.2 / 31	304 / 180		30
	Tn	5	31.2 / 29				
GROUP 2	Qvoma	15	27.8 / 29			Qm,Qp,Qvoasa	
	Qvoma+fa	2	28 / 26	27.5 / 26	143 / 100	Qvoma+fa, Qvomsa	28
	af	3	26.3 / 28			Qvomsa+fs, Qvomsc+fs	
						Qwa, Qyaac, Quaca, Quacs	
						Qyas, Qyes, Qyfa	
						Qyfs, Qyfsa, Qywa	
GROUP 3	Qls	8	18 / 16	18 / 16	260 / 190		18

Table 2.1. Summary of the Shear Strength Statistics for the Anaheim and Newport Beach Quadrangles.

SHEAR STRENGTH GROUPS FOR THE ANAHEIM AND NEWPORT BEACH QUADRANGLES

GROUP 1	GROUP 2	GROUP 3
Tm	Qm	Qls
Tcs	Qp	
Tcs?	Qvoasa	
Tn	Qvoma	
	Qvoma+fa	
	Qvomsa	
	Qvomsa+fs	
	Qvomsc+fs	
	Qwa	
	Qyaac	
	Qyaca	
	Qyacs	
	Qyas	
	Qyes	
	Qyfa	
	Qyfs	
	Qyfsa	
	Qywa	

Table 2.2. Summary of the Shear Strength Groups for the Anaheim and Newport Beach Quadrangles.

PART II

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Design Strong-Motion Record

To evaluate earthquake-induced landslide hazard potential in the study area, a method of dynamic slope stability analysis developed by Newmark (1965) was used. The Newmark method analyzes dynamic slope stability by calculating the cumulative down-slope displacement for a given earthquake strong-motion time history. As implemented for the preparation of earthquake-induced landslide zones, the Newmark method necessitates the selection of a design earthquake strong-motion record to provide the "ground shaking opportunity." For the Anaheim and Newport Beach quadrangles, selection of a strong motion record was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10% probability of being exceeded in 50 years (Petersen and others, 1996). The parameters used in the record selection are:

Modal Magnitude:	6.7 to 6.9
Modal Distance:	2.5 to 14 km
PGA:	0.35 to 42 g

The strong-motion record selected was the Channel 3 (north horizontal component) USC Station # 14 recording from the magnitude 6.7 Northridge earthquake (Trifunac and others, 1994). This record had a source to recording site distance of 8.5 km and a PGA of 0.59 g. The selected strong-motion record was not scaled or otherwise modified prior to analysis.

Displacement Calculation

The design strong-motion record was used to develop a relationship between landslide displacement and yield acceleration (a_y), defined as the earthquake horizontal ground acceleration above which landslide displacements take place. This relationship was prepared by integrating the design strong-motion record twice for a given acceleration value to find the corresponding displacement, and the process was repeated for a range of acceleration values (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for the design strong-motion record. This curve provides the required link between anticipated earthquake shaking and estimates of displacement for different combinations of geologic materials and slope gradient, as described in the Slope Stability Analysis section below.

The amount of displacement predicted by the Newmark analysis provides an indication of the relative amount of damage that could be caused by earthquake-induced landsliding. Displacements of 30, 15 and 5 cm were used as criteria for rating levels of earthquake-induced landslide hazard potential based on the work of Youd (1980), Wilson and Keefer (1983), and a DMG pilot study for earthquake-induced landslides (McCrink and Real, 1996). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.076, 0.129 and 0.232g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant in the Anaheim and Newport Beach quadrangles.

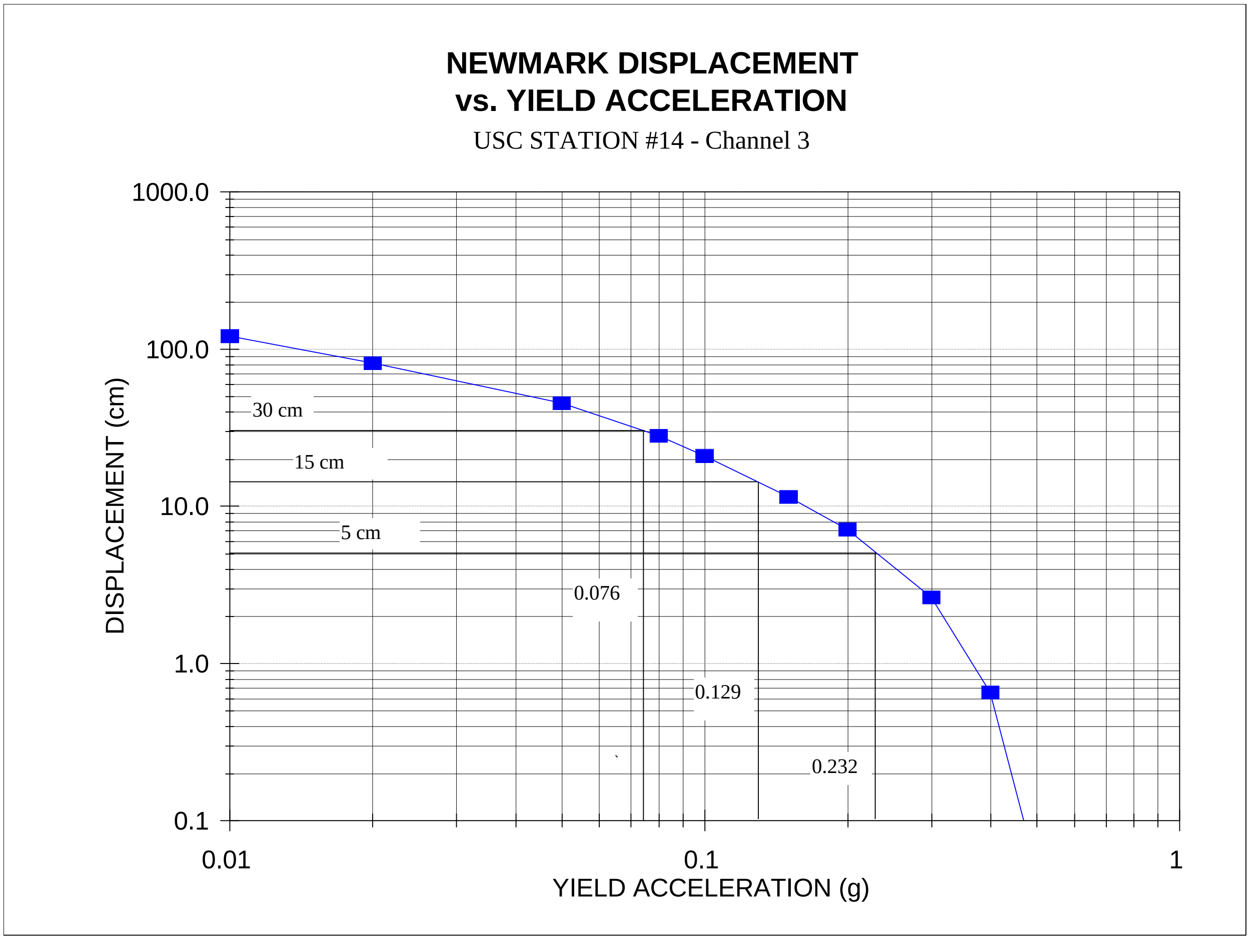

Figure 2.1. Yield Acceleration vs. Newmark Displacement for the USC Station # 14 Strong-Motion Record From the 17 January 1994 Northridge, California Earthquake.

Slope Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by the calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where FS is the Factor of Safety, g is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure α is the same as the slope angle.

The yield accelerations resulting from Newmark's equations represent the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. Based on the relationship between yield acceleration and Newmark displacement shown in Figure 2.1, hazard potentials were assigned as follows:

1. If the calculated yield acceleration was less than 0.076g, Newmark displacement greater than 30 cm is indicated, and a HIGH hazard potential was assigned (H on Table 2.3)

2. If the calculated yield acceleration fell between 0.076 and 0.13g, Newmark displacement between 15 cm and 30 cm is indicated, and a MODERATE hazard potential was assigned (M on Table 2.3)

3. If the calculated yield acceleration fell between 0.13 and 0.23g, Newmark displacement between 5 cm and 15 cm is indicated, and a LOW hazard potential was assigned (L on Table 2.3)

4. If the calculated yield acceleration was greater than 0.23g, Newmark displacement of less than 5 cm is indicated, and a VERY LOW potential was assigned (VL on Table 2.3)

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

ANAHEIM AND NEWPORT BEACH QUADRANGLES
HAZARD POTENTIAL MATRIX

Geologic Material Group	MEAN PHI	SLOPE CATEGORY (percent): I 0-18	II 19-24	III 25-28	IV 29-32	V 33-38	VI 39-44	VII 45-49	VIII >49
1	30	VL	VL	VL	VL	L	M	M	H
2	28	VL	VL	VL	L	L	M	H	H
3	18	L	M	H	H	H	H	H	H

Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the Anaheim and Newport Beach Quadrangles. Shaded area indicates hazard potential levels included within the hazard zone. H = High, M = Moderate, L = Low, VL = Very Low.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (DOC, 2000). Under these criteria, earthquake-induced landslide hazard zones are defined as areas that meet one or both of the following conditions:

1. Areas that have been identified as having experienced landslide movement in the past, including all mappable landslide deposits and source areas as well as any landslide that is known to have been triggered by historic earthquake activity.

2. Areas where the geologic and geotechnical data and analyses indicate that the earth materials may be susceptible to earthquake-induced slope failure.

These conditions are discussed in further detail in the following sections.

Existing Landslides

Existing landslides typically consist of disrupted soils and rock materials that are generally weaker than adjacent undisturbed rock and soil materials. Previous studies indicate that existing landslides can be reactivated by earthquake movements (Keefer, 1984). Earthquake-triggered movement of existing landslides is most pronounced in steep head scarp areas and at the toe of existing landslide deposits. Although reactivation of deep-seated landslide deposits is less common (Keefer, 1984), a significant number of deep-seated landslide movements have occurred during, or soon after, several recent earthquakes. Based on these observations, all existing landslides with a definite or probable confidence rating are included within the earthquake-induced landslide hazard zone.

Geologic and Geotechnical Analysis

Based on the conclusions of a pilot study performed by DMG (McCrink and Real, 1996), it has been concluded that earthquake-induced landslide hazard zones should encompass all areas that have a High, Moderate or Low level of hazard potential (see Table 2.3). This would include all areas where the analyses indicate earthquake displacements of 5 centimeters or greater. Areas with a Very Low hazard potential, indicating less than 5 centimeters displacement, are excluded from the zone.

As summarized in Table 2.3, all areas characterized by the following geologic strength group and slope gradient conditions are included in the earthquake-induced landslide hazard zone:

1. Geologic Strength Group 3 is included for all slope gradient categories. (Note: Geologic Strength Group 3 includes all mappable landslides with a definite or probable confidence rating).
2. Geologic Strength Group 2 is included for all slopes steeper than 29 percent.
3. Geologic Strength Group 1 is included for all slopes steeper than 33 percent.

4. This results in roughly 484 acres (1.2%) of the land in the Newport Beach Quadrangle and none of the Anaheim Quadrangle lying within the earthquake-induced landslide hazard zone.

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AIR PHOTOS

Whittier-Fairchild Collection, 1927, Aerial photography, flight 113, frames 665-675, 706-717, 753-764, 797-806, 834-842, 1067-1076, and 1093-1100, black and white, vertical, approximate scale 1:18,000.

APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
City of Laguna Beach, Department of Public Works and Planning Department	**38**
Total number of tests used	**38**

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Anaheim and Newport Beach 7.5-Minute Quadrangles, Orange County, California

By

Mark D. Petersen*, Chris H. Cramer*, Geoffrey A. Faneros, Charles R. Real, and Michael S. Reichle

California Department of Conservation
Division of Mines and Geology
***Formerly with DMG, now with U.S. Geological Survey**

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included areground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5-minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the “Simple Prescribed Parameter Value” method (SPPV) described in the site investigation guidelines (California Department of Conservation, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2 (addressing liquefaction and earthquake-induced landslide hazards) constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on DMG’s Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology, and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10% probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

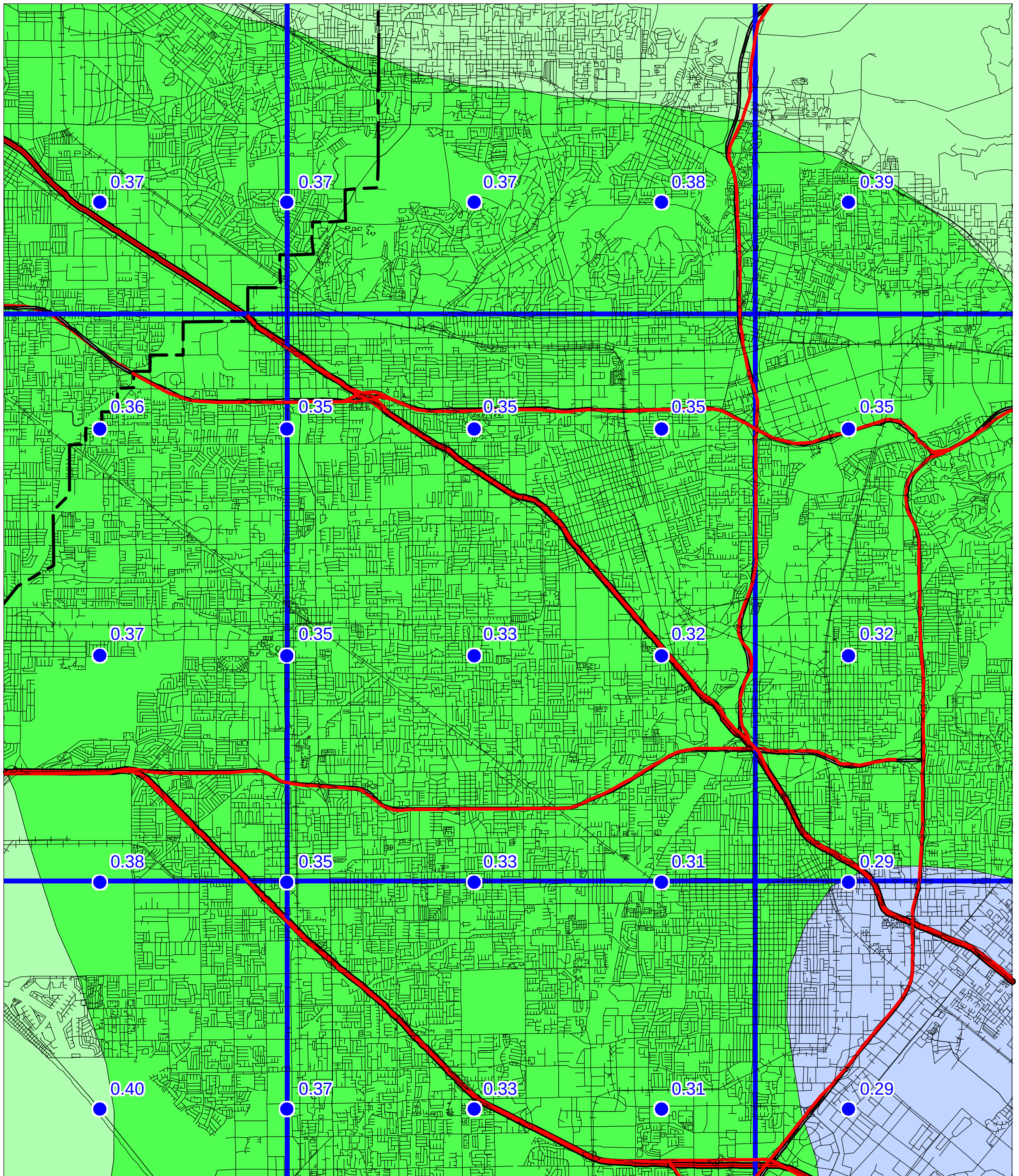
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1a and 3.1b through 3.3a and 3.3 b show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight adjacent

ANAHEIM 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

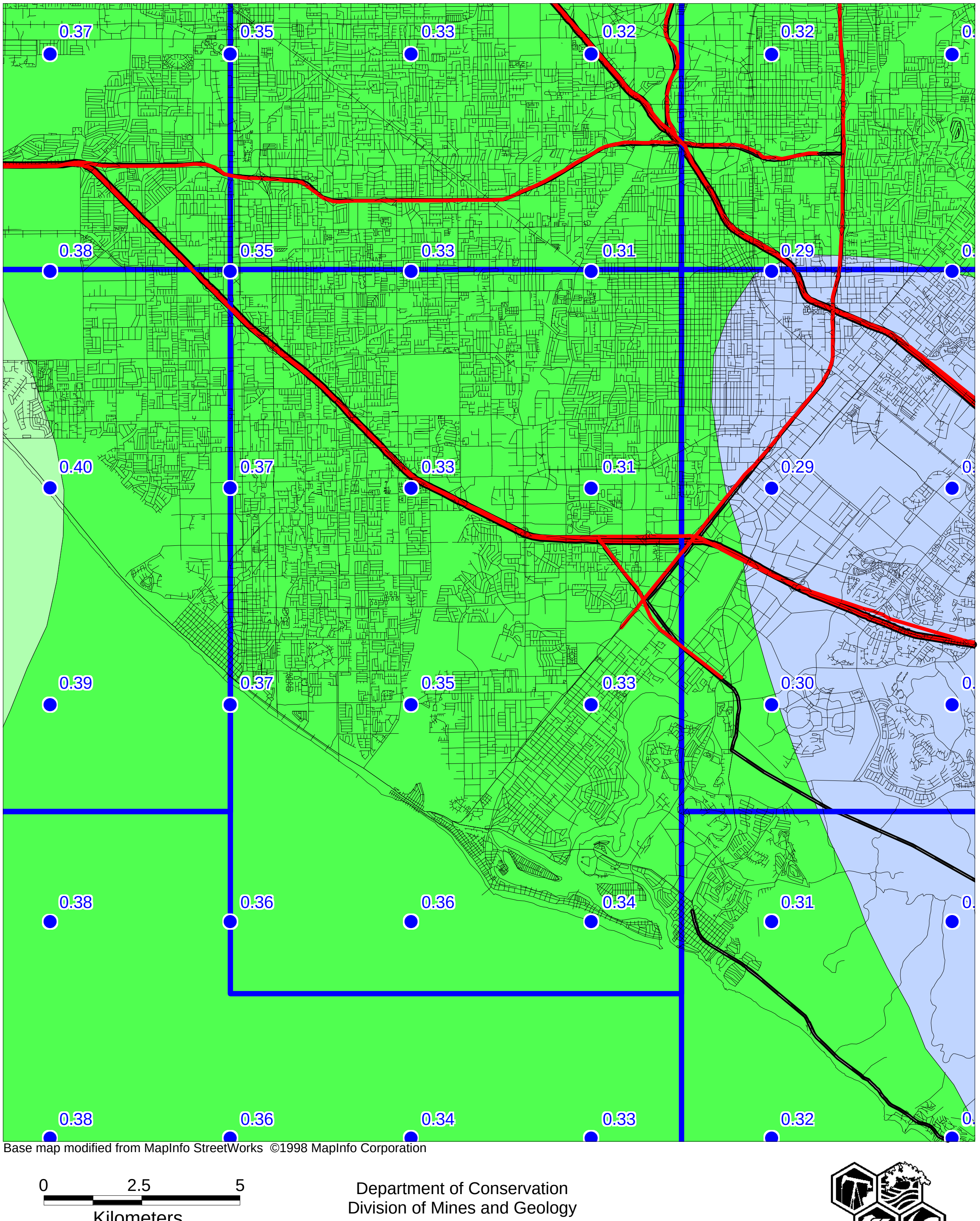
Figure 3.1

NEWPORT BEACH 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation

Department of Conservation
Division of Mines and Geology

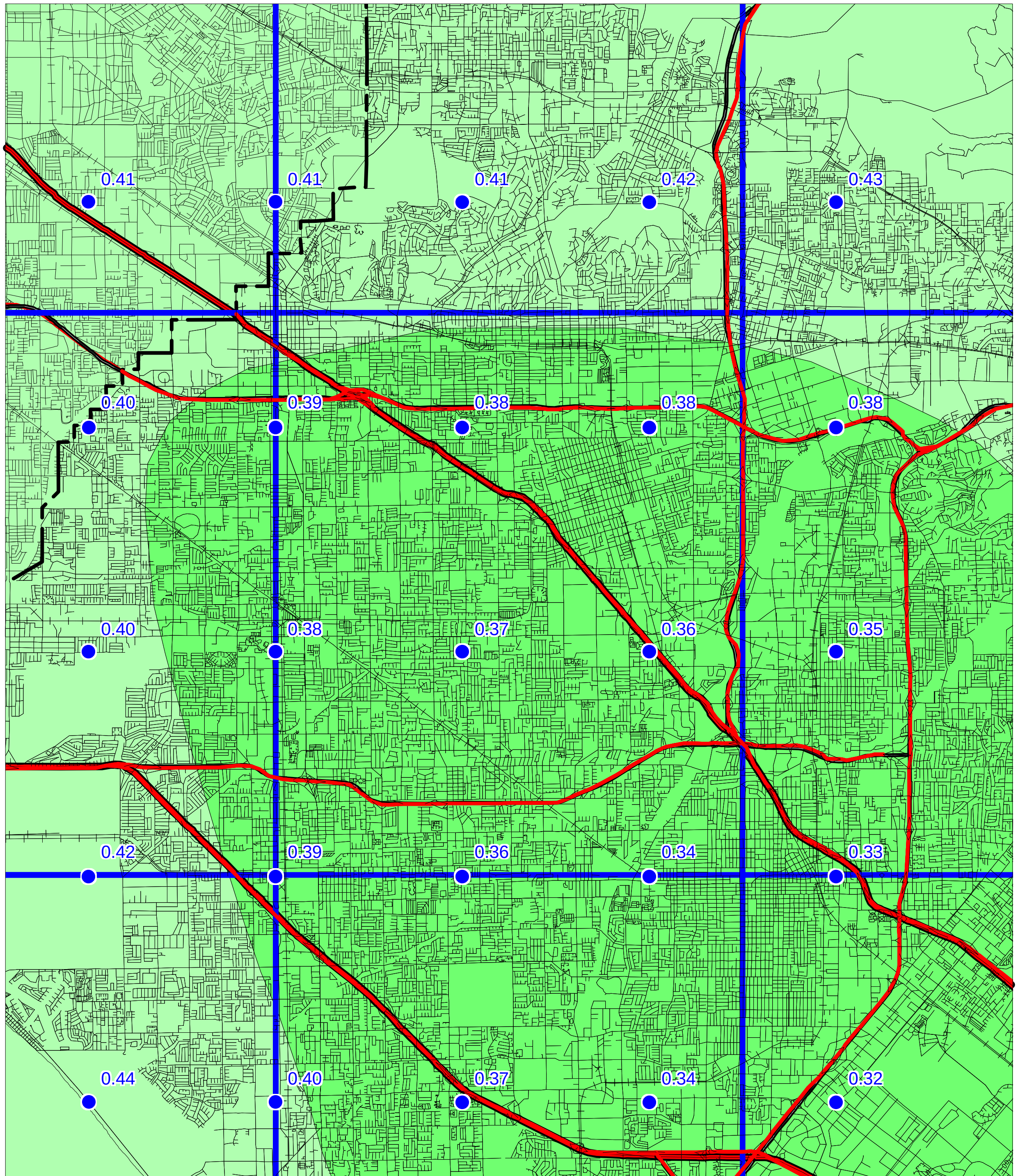
Figure 3.1

ANAHEIM 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 2.5 5

Kilometers

Department of Conservation
Division of Mines and Geology

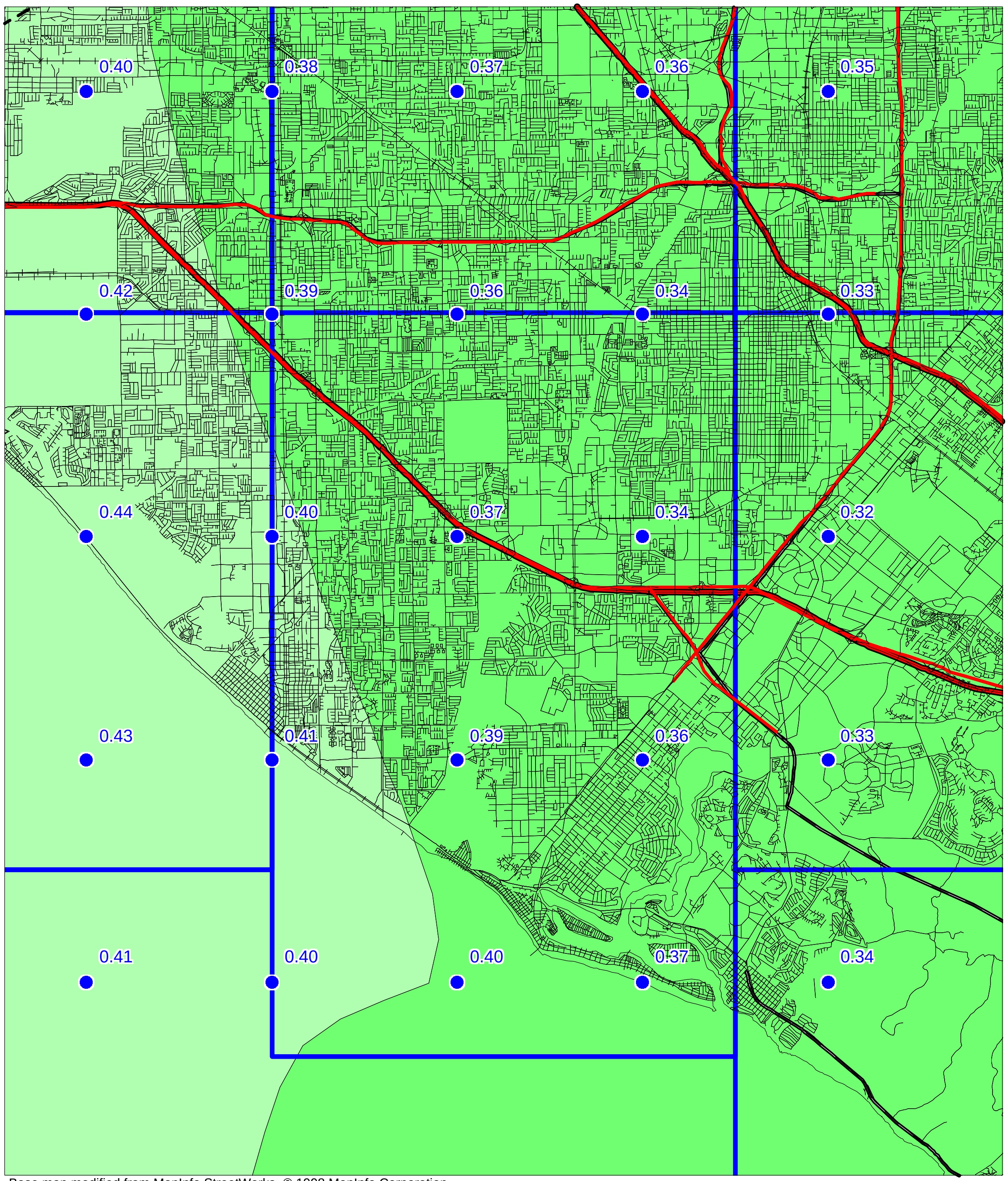
Figure 3.2

NEWPORT BEACH 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

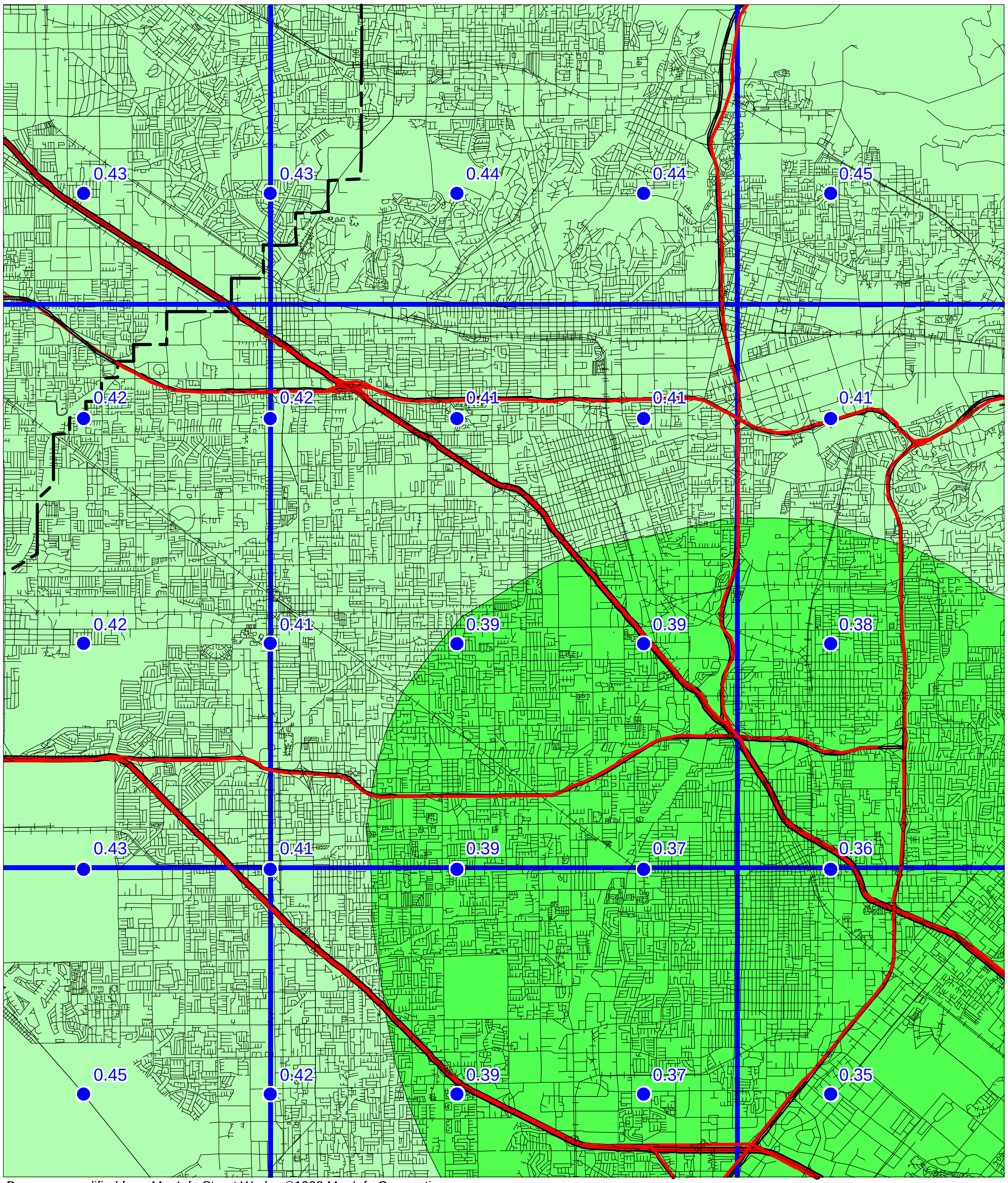
Figure 3.2

ANAHEIM 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS



Base map modified from MapInfo Street Works ©1998 MapInfo Corporation

0 2.5 5

Kilometers

Department of Conservation
Division of Mines and Geology

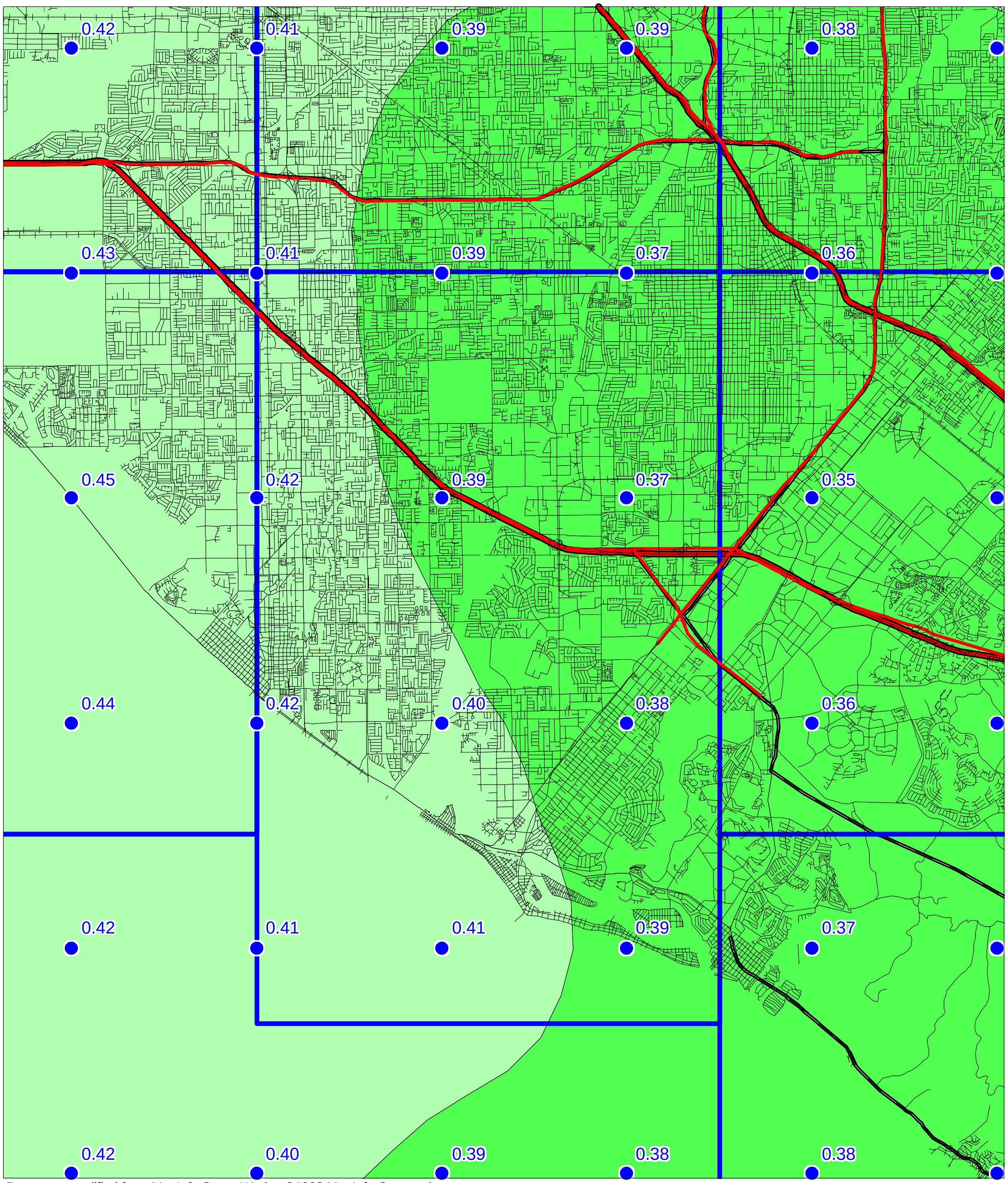
Figure 3.3

NEWPORT BEACH 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS



Base map modified from MapInfo Street Works ©1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.3

quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The maps in Figure 3.4a and Figure 3.4b identify the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10% probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4a or 3.4b and PGA from Figure 3.3a or 3.3b (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

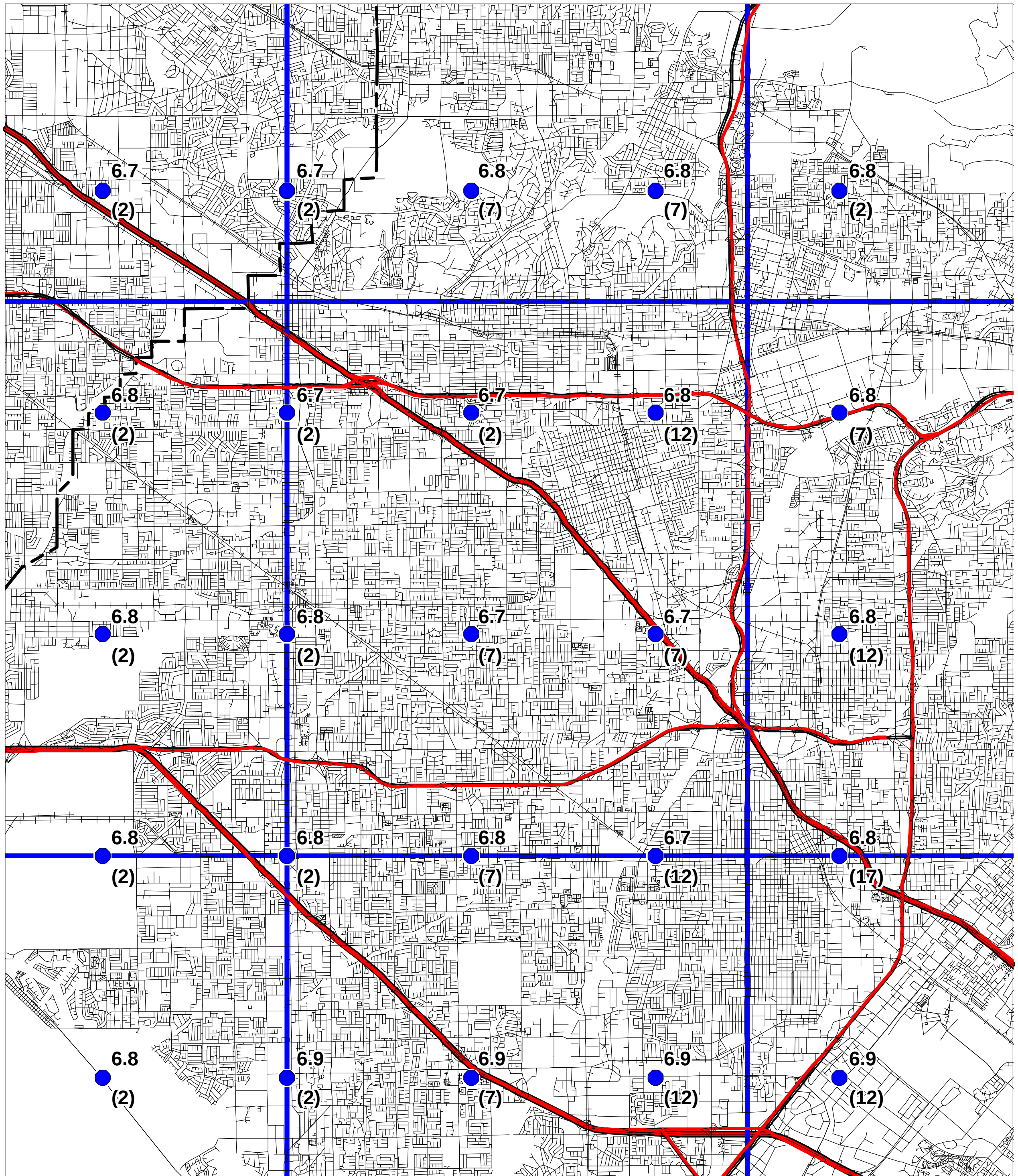
1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation

ANAHEIM 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

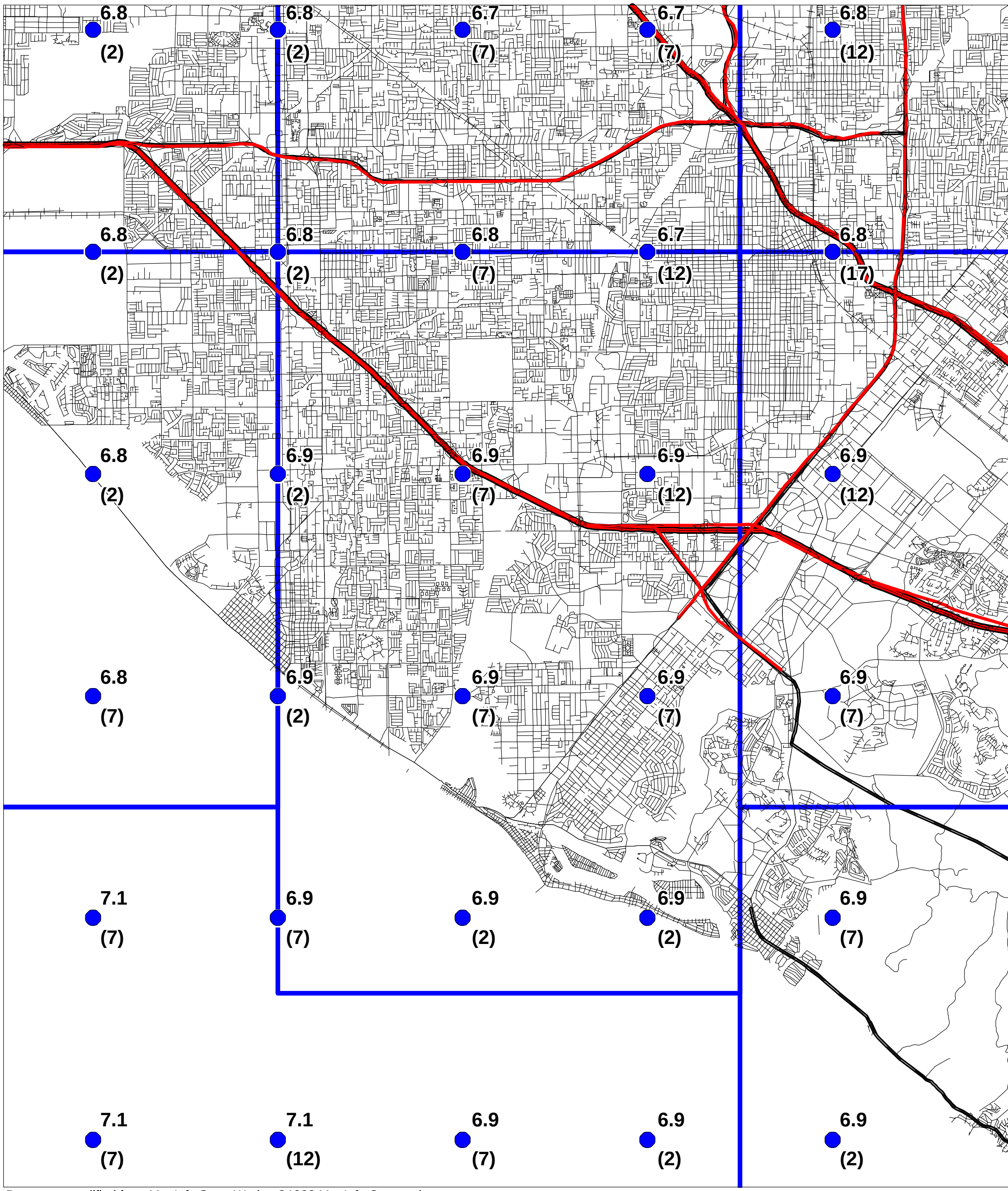
Figure 3.4

NEWPORT BEACH 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

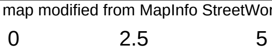
10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation



Department of Conservation
Division of Mines and Geology

Figure 3.4

of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

3. Uncertainties in the hazard values have been estimated to be about +/- 50% of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not previously been recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (DOC, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1a/b, 3.2a/b, and 3.3a/b, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1a/b, 3.2a/b, or 3.3a/b should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the “importance” or sensitivity of the proposed building with regard to occupant safety.

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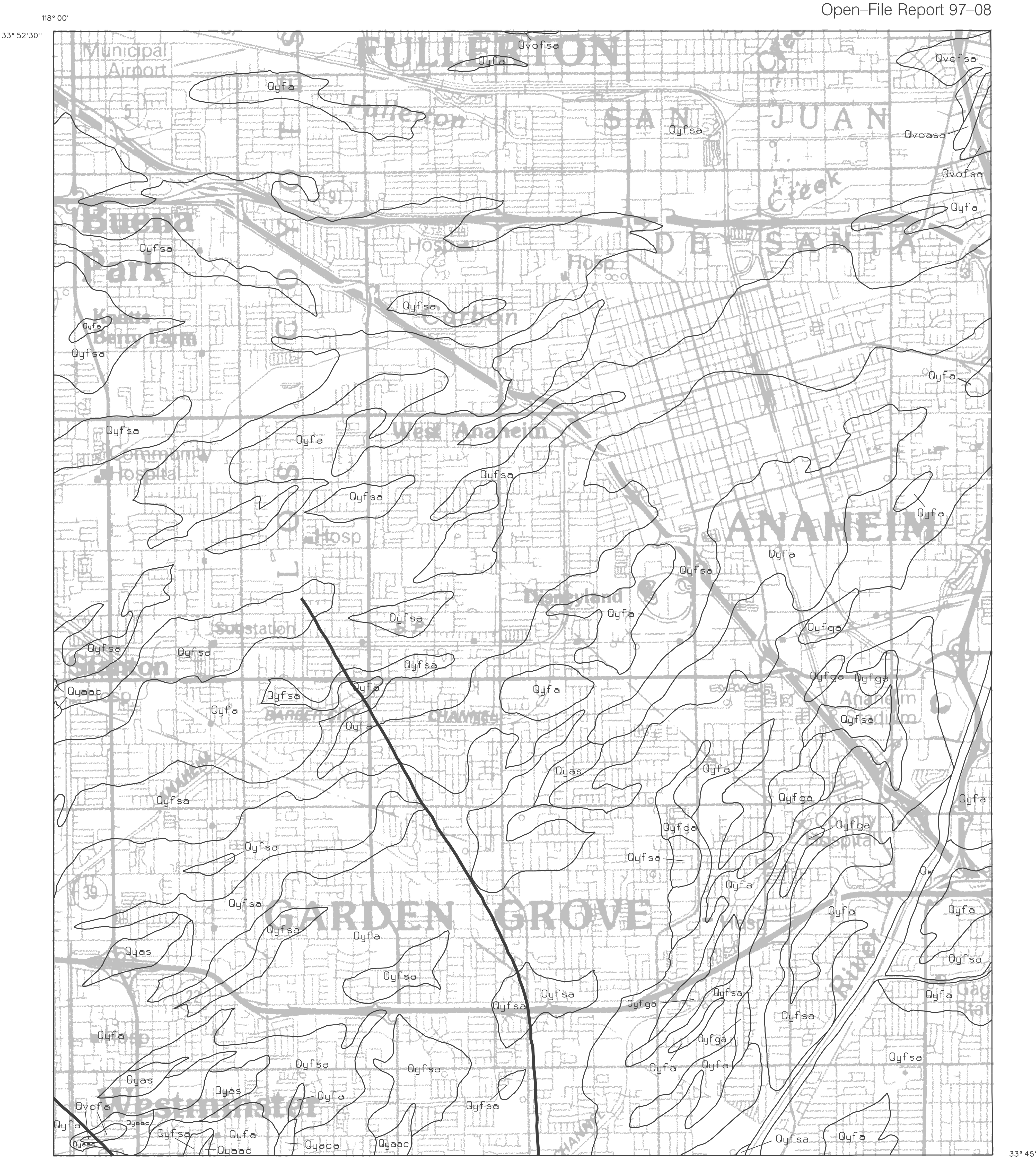


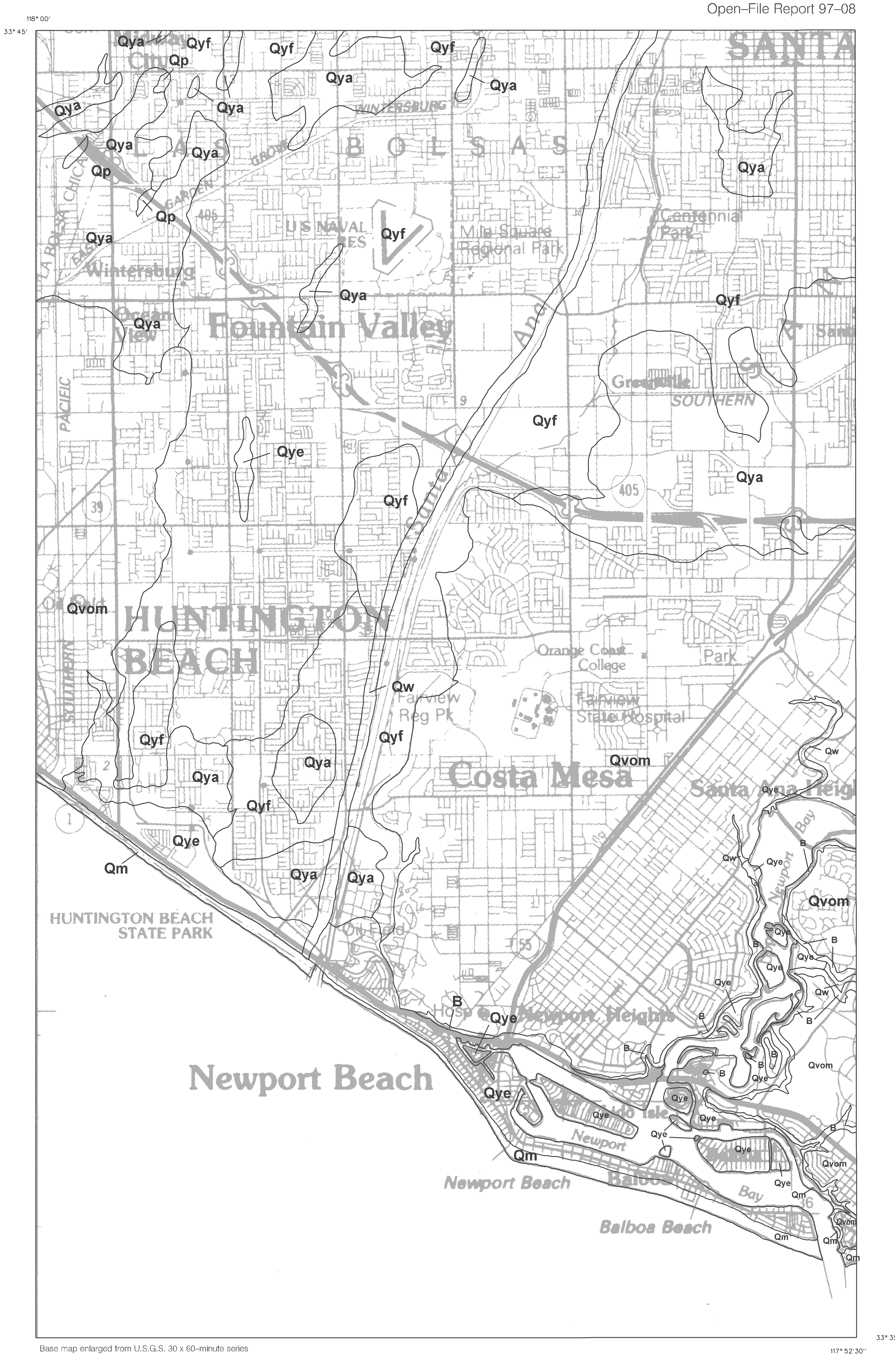
Base map enlarged from U.S.G.S. 30 x 60–minute series

B = Pre–Quaternary bedrock.
See Geologic Conditions section in report for descriptions of the units.

ONE MILE
SCALE

Fault Line

Plate 1.1 Quaternary Geologic Map of the Anaheim 7.5–minute Quadrangle.



Base map enlarged from U.S.G.S. 30 x 60–minute series

B = Pre-Quaternary bedrock.
See "Bedrock and Surficial Geology" in Section 1 of report for descriptions of units.

ONE MILE
SCALE

Plate 1.1 Quaternary Geologic Map of the Newport Beach 7.5-minute quadrangle.

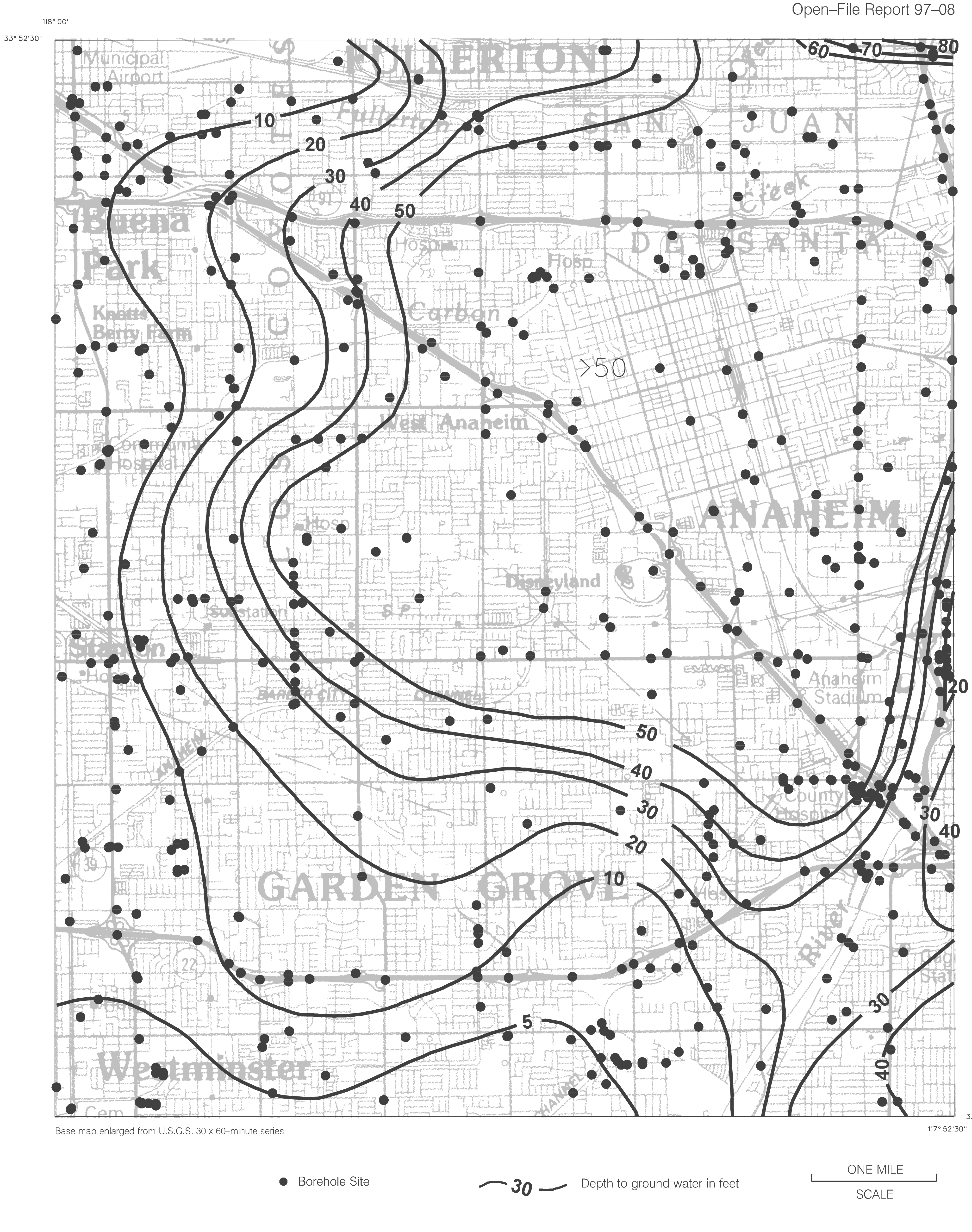
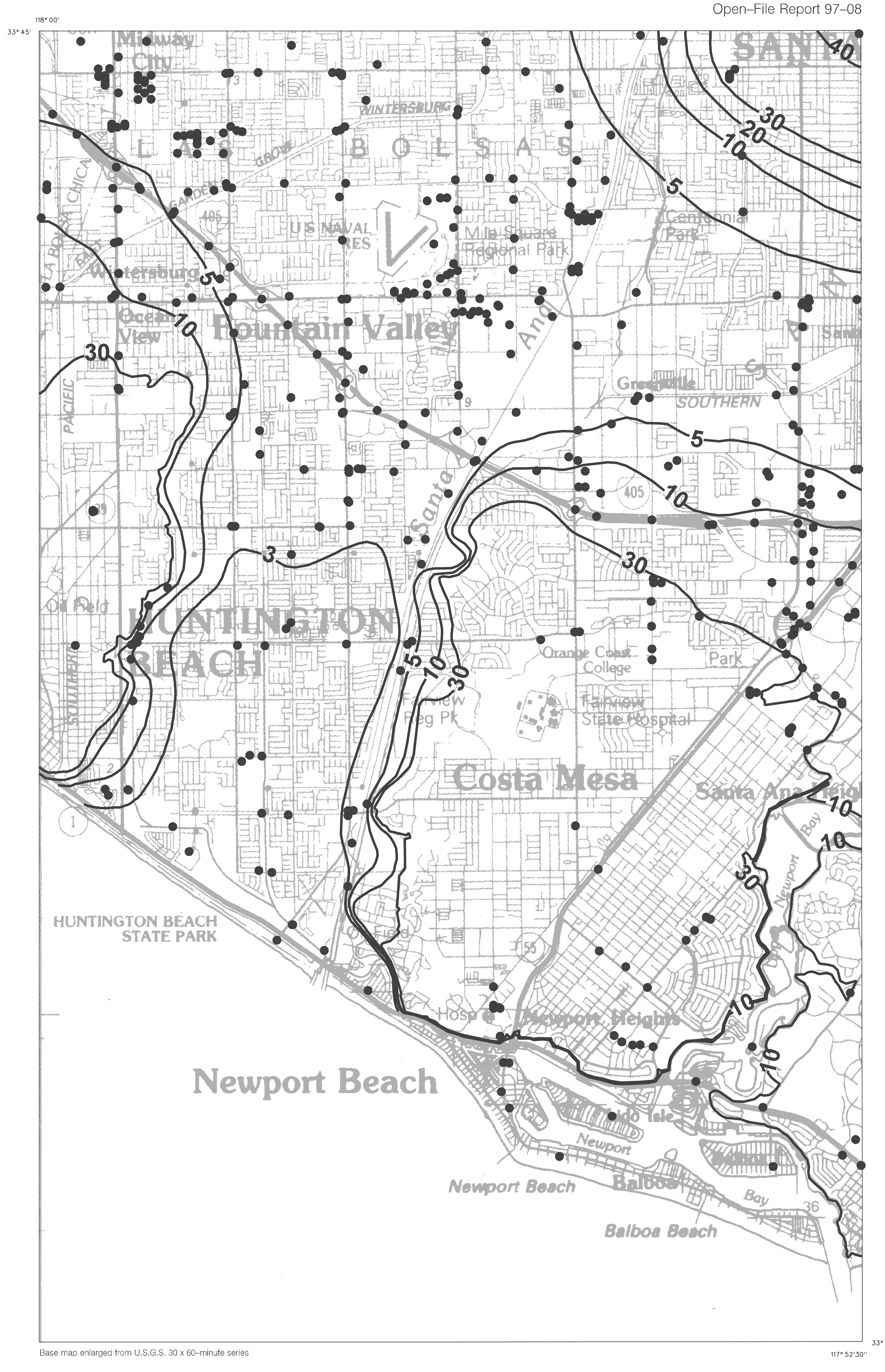


Plate 1.2 Historically Highest Ground Water Contours and Borehole Log Data Locations, Anaheim 7.5–minute Quadrangle.



Base map enlarged from U.S.G.S. 30 x 60–minute series

● Borehole Site

30 Depth to ground water in feet

ONE MILE
SCALE

Plate 1.2 Historically Highest Ground Water Contours and Borehole Log Data Locations, Newport Beach Quadrangle.